

REMARKS/ARGUMENTS

1. Applicants acknowledge with appreciation the courtesy of a telephonic interview on March 30, 2006 between Examiner Angela Martin and Applicants' Attorney Jeffrey Klayman to discuss the Office action of December 9, 2005.

Mr. Klayman explained that Muthuswamy does not teach or suggest an anode-supported solid oxide fuel cell because the claim term "supporting" relates to mechanical/structural support, as provided in the specification at page 9, line 2, and Muthuswamy's fuel cells require additional materials for rigidity. Mr. Klayman also explained that the references showing cathode-supported solid oxide fuel cells do not anticipate an anode-supported solid oxide fuel cell because an anode-supported solid oxide fuel cell is not merely a reversal of a cathode-supported solid oxide fuel cell, using an example that just because one can construct a building using a cement foundation to support a wood structure does not mean that one would construct a building using a wood foundation to support a cement structure.

Examiner Martin explained that the claim wording "capable of supporting" did not require that the anode actually support the fuel cell, and also argued that the word "comprising" did not preclude added materials for rigidity, for example, a metal foam core as in Muthuswamy.

No agreement regarding allowable subject matter was reached.

2. The Examiner rejected claim 32 under 35 U.S.C. 102(e) as being anticipated by Muthuswamy; rejected claims 32-35 and 54 under 35 U.S.C. 103(a) as being anticipated by Muthuswamy and Kendall; rejected claims 1-13, 16, 29-31, 87, and 91 under 102(b) or 103(a) as being anticipated by Muthuswamy or Kendall; rejected claims 32, 38, 39, and 54 under 35 U.S.C. 103(a) as being anticipated by

Muthuswamy and Ruka '700; rejected claims 32, 40-43, 48-52, and 54 under 35 U.S.C. 103(a) as being anticipated by Muthuswamy and Ruka '713; and rejected claims 29, 32, 36-38, 53, 54, and 88-90 under 35 U.S.C. 103(a) as being anticipated by Muthuswamy and Stover. The Examiner indicated that claims 36, 37, 44-47, and 88-90 contain allowable subject matter, but it appears that claims 36, 37, and 88-90 in fact stand rejected as being anticipated by Muthuswamy and Stover.

As is well known, in order for a reference or combination of references to anticipate a claim, the reference(s) must teach or reasonably suggest each and every claim limitation. In rejecting claims under 35 U.S.C. § 103, the examiner bears the initial burden of presenting a *prima facie* case of obviousness. See *In re Rijckaert*, 9 F.3d 1531, 1532, 28 USPQ2d 1955, 1956 (Fed. Cir. 1993). A *prima facie* case of obviousness is established by presenting evidence that the applied prior art teachings would appear to be sufficient for one of ordinary skill in the relevant art having the applied prior art before him to make the proposed modification. See *In re Lintner*, 9 F.2d 1013, 1016, 173 USPQ 560, 562 (CCPA 1972). Furthermore, the conclusion that the claimed subject matter is *prima facie* obvious must be supported by evidence, as shown by some objective teaching in the applied prior art or by knowledge generally available to one of ordinary skill in the art that would have led that individual to modify the relevant teachings of the applied prior art to arrive at the claimed invention. See *In re Fine*, 837 F.2d 1071, 1074, 5 USPQ2d 1596, 1598 (Fed. Cir. 1988). Rejections based on § 103 must rest on a factual basis with these facts being interpreted without hindsight reconstruction of the invention from the prior art. The examiner may not, because of doubt that the invention is patentable, resort to speculation, unfounded assumption or hindsight reconstruction to supply deficiencies in the factual basis for the rejection. See *In re Warner*, 379 F.2d 1011, 1017, 154 USPQ 173, 177 (CCPA 1967), cert. denied, 389 U.S. 1057 (1968).

All of the pending claims depend either directly or indirectly from independent claim 32. Independent claim 32 is directed to an anode-supported solid oxide fuel cell. As known in the art, solid oxide fuel cells use hard, non-porous ceramic electrolytes and operate at very high temperatures (e.g., 500-1000 degrees Celsius). The attachment provides a good description of different types of fuel cells, including solid oxide and solid polymer fuel cells.

Claim 32 is deemed by the Examiner to be anticipated by, or obvious in view of, Muthuswamy, either alone or in combination with Kendall, Ruka '700, Ruka '713, or Stover. Upon further review of Muthuswamy, it is clear that claim 32 cannot possibly be anticipated by, or obvious in view of, Muthuswamy, because Muthuswamy does not relate to solid oxide fuel cells, but rather relates to solid polymer fuel cells (see, for example, Muthuswamy's abstract). As described in the attachment, solid polymer fuel cells use a solid polymer electrolyte and operate at relatively low temperatures, around 80°C (176°F). Thus, even though both the subject patent application and Muthuswamy relate to fuel cells, Muthuswamy must be considered as non-analogous art because solid oxide fuel cells and solid polymer fuel cells are made from vastly different materials and processes and operate in completely different ways and environments.

By way of example, Muthuswamy's fuel cells use a solid polymer electrolyte and electrodes made from paper or cloth. Muthuswamy can use these types of materials because of the low operating temperature of his fuel cells, and also because additional rigidity is provided by an inner and/or outer layer of reticulated vitreous aluminum or carbon. Trying to apply the teachings of Muthuswamy to solid oxide fuel cells would be like trying to build a skyscraper based on the blueprints for a typical single family house. Arguably none of the materials or processes discussed by Muthuswamy are applicable to the fabrication of solid oxide fuel cells. For example, one would not fabricate a solid

oxide fuel cell using the process steps described by Muthuswamy. Furthermore, at the operating temperatures of a solid oxide fuel cell, a solid polymer would melt, cloth or paper electrodes would likely disintegrate, and even the reticulated vitreous aluminum or carbon material that is used for rigidity would likely be destroyed by the high-temperature exposure to fuel and/or air. Thus, Muthuswamy would not have taught a person of ordinary skill in the art how to make and use a solid oxide fuel cell (although Muthuswamy would arguably be a good example of how NOT to make a solid oxide fuel cell).

Furthermore, as previously presented by Applicants' Attorneys, Muthuswamy's fuel cells require a reticulated vitreous aluminum or carbon material as the inner core and/or outer layer for rigidity. Muthuswamy's anode would not support the fuel cell at the operating pressures described by Muthuswamy even at the low temperatures at which the fuel cell operates, and therefore an additional material is required to provide rigidity. Thus, Muthuswamy does not teach or otherwise suggest an anode-supported fuel cell (or, for that matter, a cathode-supported or electrolyte-supported fuel cell) in the context of the present patent application.

Regarding the combination of Muthuswamy and Ruka '700, the fact that Ruka teaches a cathode-supported solid oxide fuel cell does not render claim 32 obvious because Ruka would not have taught a person of ordinary skill in the art how to make and use an anode-supported solid oxide fuel cell as claimed. On the surface, it might seem logical to look at Ruka's cathode-supported fuel cell and simply suggest a reversal of polarity so that the anode, rather than the cathode, supports the fuel cell. In practice, however, such a reversal of polarity requires more than merely fabricating Ruka's fuel cell in reverse. The materials and processes used to fabricate a solid oxide fuel cell starting with the cathode differ from the materials and processes used to fabricate a solid oxide fuel cell starting with the anode. One reason for such differences is that in the cathode-

supported fuel cell, the cathode requires specialized materials and processes to closely match its coefficient of thermal expansion with that of the electrolyte, whereas in the claimed anode-supported fuel cell, the electrolyte and cathode are thin layers that do not require such close matching and so the cathode can be formed using simpler materials and processes. Another reason for such differences is that in the cathode-supported fuel cell, the anode material is applied last and therefore can be formed using simple materials and processes (e.g., nickel-zirconia or cobalt-zirconia), whereas in the claimed anode-supported fuel cell, the anode material is typically formed from a metal oxide (e.g., nickel oxide) in order to withstand subsequent high-temperature processes and is subsequently reduced to base metal (e.g., nickel) in order to provide the necessary porosity. Thus, even if a person of ordinary skill in the art had realized the potential benefits of an anode-supported solid oxide fuel cell, that person would not have found a blueprint in Ruka with or without reference to Muthuswamy.

The inventors of the subject patent were well aware of electrolyte-supported and cathode-supported solid oxide fuel cells, as evinced by the discussion at page 7, line 2 through page 8, line 26. Even with this knowledge, the inventors expended great time and effort to figure out how to make and use anode-supported solid oxide fuel cells, and disclosed numerous embodiments in the subject patent application with sufficient detail so as to enable those of ordinary skill in the art to make and use such anode-supported solid oxide fuel cells. The Applicants are therefore entitled to claims covering anode-supported solid oxide fuel cells.

Because none of the references alone or in combination teach or otherwise suggest an anode-supported solid oxide fuel cell, the Office action fails to set forth a *prima facie* basis for rejection of claim 32. "To establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or

suggested by the prior art. In re Royka, 490 F.2d 981, 180 USPQ 580 (CCPA 1974)." MPEP § 2143.03. Consequently, the Examiner's suggestion to combine references can only come from hindsight. A skilled artisan could certainly use the teachings of the subject patent application as a "road map" to build the claimed invention so as to include various elements of the cited references, but there is nothing in those references to suggest the claimed invention, and additional elements need to be added over those references to result in the claimed invention. Furthermore, the chain of references including Muthuswamy, Kendall, and Ruka show that there was a long but unsatisfied need for an anode-supported solid oxide fuel cell and all of the various advantages such an anode-supported solid oxide fuel cell provides over electrolyte and cathode supported solid oxide fuel cells.

Thus, Applicants respectfully submit that independent claim 32 and its dependents are allowable over the cited references.

3. Applicants have amended claim 32 to remove the "capable of" wording that was objected to by the Examiner, and also to clarify that the term "support" refers to mechanical/structural support, as discussed at page 9, line 2 of the subject patent application, such that the anode provides the structural integrity of the solid oxide fuel cell, and the electrolyte and cathode are of insufficient strength to support the solid oxide fuel cell.

4. All pending claims are believed to be in a form suitable for allowance. Therefore, the application is believed to be in a condition for allowance. The Applicant respectfully requests early allowance of the application. The Applicant requests that the Examiner contact the undersigned, Jeffrey T. Klayman, if it will assist further examination of this application.

5. Applicants petition for a one month extension of time. In the event that a further extension is needed, this conditional petition of extension is hereby submitted, and Applicants request that deposit account number 19-4972 be charged for any fees that may be required for the timely consideration of this application.

Respectfully submitted,



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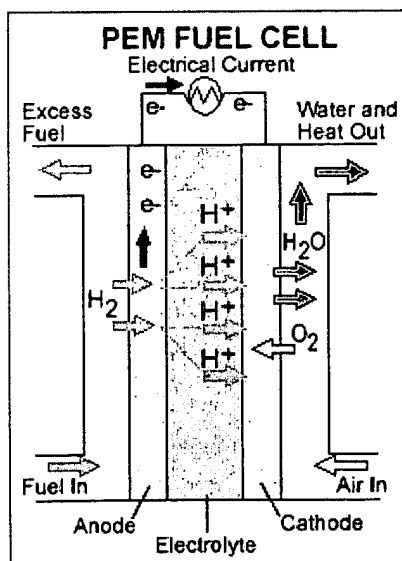
Types of Fuel Cells

Fuel cells are classified primarily by the kind of electrolyte they employ. This determines the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications. Learn more about:

- [Polymer Electrolyte Membrane \(PEM\) Fuel Cells](#)
- [Direct Methanol Fuel Cells](#)
- [Alkaline Fuel Cells](#)
- [Phosphoric Acid Fuel Cells](#)
- [Molten Carbonate Fuel Cells](#)
- [Solid Oxide Fuel Cells](#)
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Polymer Electrolyte Membrane (PEM) Fuel Cells

Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume, compared to other fuel cells. PEM fuel



cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like some fuel cells. They are typically fueled with pure hydrogen supplied from storage tanks or onboard reformers.

Polymer electrolyte membrane fuel cells operate at relatively low temperatures, around 80°C (176°F). Low temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability. However, it requires that a noble-metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons, adding to system cost. The platinum catalyst is also extremely sensitive to CO poisoning, making it necessary to employ an additional reactor to reduce CO in the fuel gas if the hydrogen is derived from an alcohol or hydrocarbon fuel. This also adds cost. Developers are currently exploring platinum/ruthenium catalysts that are more resistant to CO.

PEM fuel cells are used primarily for transportation applications and some stationary applications. Due to their fast startup time, low sensitivity to orientation, and favorable power-to-weight ratio, PEM fuel cells are particularly suitable for use in passenger vehicles, such as cars and buses.

A significant barrier to using these fuel cells in vehicles is hydrogen storage. Most fuel cell vehicles (FCVs) powered by pure hydrogen must store the hydrogen onboard as a compressed gas in pressurized tanks. Due to the low energy density of hydrogen, it is difficult to store enough hydrogen onboard to allow vehicles to travel the same distance as gasoline-powered vehicles before refueling, typically 300-400 miles. Higher-density liquid fuels such as methanol, ethanol, natural gas, liquefied petroleum gas, and gasoline can be used for fuel, but the vehicles must have an onboard fuel processor to reform the methanol to hydrogen. This increases costs and maintenance requirements. The reformer also releases carbon dioxide (a greenhouse gas), though less than that emitted from current gasoline-powered engines.

Direct Methanol Fuel Cells

Most fuel cells are powered by hydrogen, which can be fed to the fuel cell system directly or can be generated within the fuel cell system by

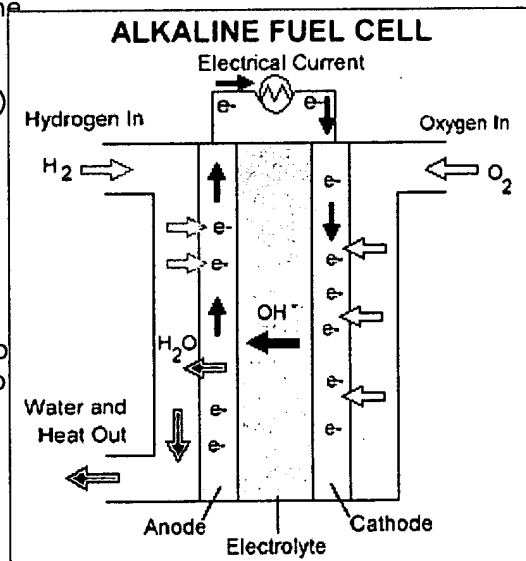
reforming hydrogen-rich fuels such as methanol, ethanol, and hydrocarbon fuels. Direct methanol fuel cells (DMFCs), however, are powered by pure methanol, which is mixed with steam and fed directly to the fuel cell anode.

Direct methanol fuel cells do not have many of the fuel storage problems typical of some fuel cells since methanol has a higher energy density than hydrogen—though less than gasoline or diesel fuel. Methanol is also easier to transport and supply to the public using our current infrastructure since it is a liquid, like gasoline.

Direct methanol fuel cell technology is relatively new compared to that of fuel cells powered by pure hydrogen, and DMFC research and development are roughly 3-4 years behind that for other fuel cell types.

Alkaline Fuel Cells

Alkaline fuel cells (AFCs) were one of the first fuel cell technologies developed and they were the first type widely



used in the U.S. space program to produce electrical energy and water onboard spacecraft. These fuel cells use a solution of potassium hydroxide in water as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. High-temperature AFCs operate at temperatures between 100°C and 250°C (212°F and 482°F). However, newer AFC designs operate at lower temperatures of roughly 23°C to 70°C (74°F to 158°F).

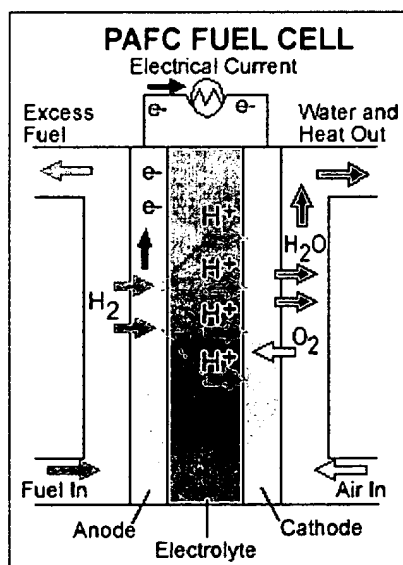
AFCs' high performance is due to the rate at which chemical reactions take place in the cell. They have also demonstrated efficiencies near 60 percent in space applications.

The disadvantage of this fuel cell type is that it is easily poisoned by carbon dioxide (CO_2). In fact, even the small amount of CO_2 in the air can affect this cell's operation, making it necessary to purify both the hydrogen and oxygen used in the cell. This purification process is costly. Susceptibility to poisoning also affects the cell's lifetime (the amount of time before it must be replaced), further adding to cost.

Cost is less of a factor for remote locations such as space or under the sea. However, to effectively compete in most mainstream commercial markets, these fuel cells will have to become more cost-effective. AFC stacks have been shown to maintain sufficiently stable operation for more than 8,000 operating hours. To be economically viable in large-scale utility applications, these fuel cells need to reach operating times exceeding 40,000 hours, something that has not yet been achieved due to material durability issues. This is possibly the most significant obstacle in commercializing this fuel cell technology.

Phosphoric Acid Fuel Cells

Phosphoric acid fuel cells use liquid phosphoric acid as an electrolyte—the acid is contained in a Teflon-bonded silicon carbide matrix—and porous carbon electrodes containing a platinum catalyst. The chemical reactions that take place in the cell are shown in the diagram to the right.

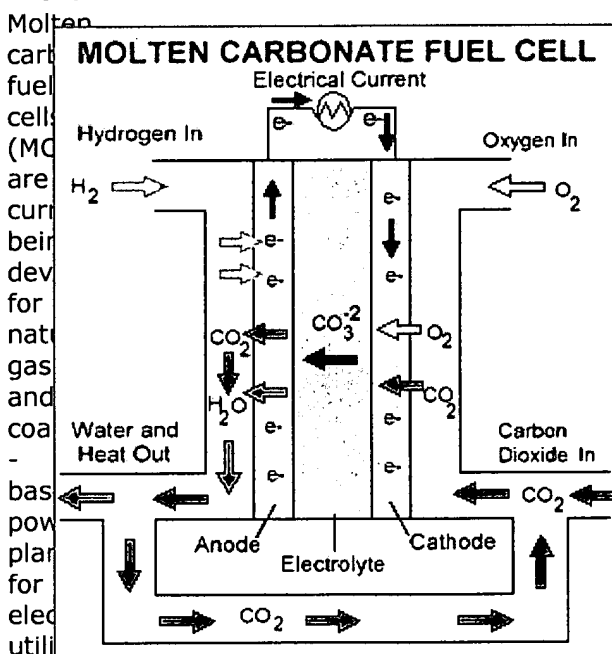


The phosphoric acid fuel cell (PAFC) is considered the "first generation" of modern fuel cells. It is one of the most mature cell types and the first to be used commercially, with over 200 units currently in use. This type of fuel cell is typically used for stationary power generation, but some PAFCs have been used to power large vehicles such as city buses.

PAFCs are more tolerant of impurities in fossil

fuels that have been reformed into hydrogen than PEM cells, which are easily "poisoned" by carbon monoxide—carbon monoxide binds to the platinum catalyst at the anode, decreasing the fuel cell's efficiency. They are 85 percent efficient when used for the co-generation of electricity and heat, but less efficient at generating electricity alone (37 to 42 percent). This is only slightly more efficient than combustion-based power plants, which typically operate at 33 to 35 percent efficiency. PAFCs are also less powerful than other fuel cells, given the same weight and volume. As a result, these fuel cells are typically large and heavy. PAFCs are also expensive. Like PEM fuel cells, PAFCs require an expensive platinum catalyst, which raises the cost of the fuel cell. A typical phosphoric acid fuel cell costs between \$4,000 and \$4,500 per kilowatt to operate.

Molten Carbonate Fuel Cells



industrial, and military applications. MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide (LiAlO₂) matrix. Since they operate at extremely high temperatures of 650°C (roughly 1,200°F) and above, non-precious metals can be used as catalysts at the anode and cathode, reducing costs.

Improved efficiency is another reason MCFCs offer significant cost reductions over phosphoric acid fuel cells (PAFCs). Molten carbonate fuel cells can reach efficiencies approaching 60 percent, considerably higher than the 37-42

percent efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall fuel efficiencies can be as high as 85 percent.

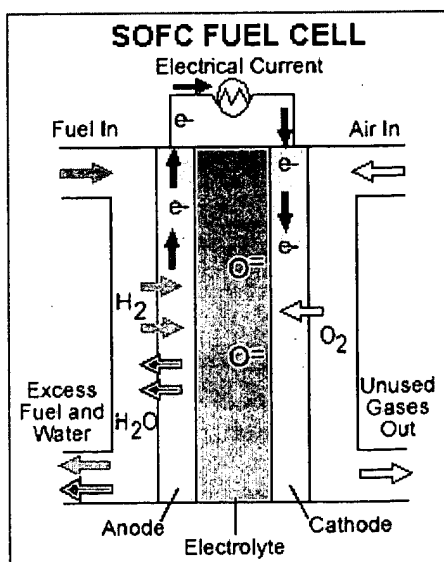
Unlike alkaline, phosphoric acid, and polymer electrolyte membrane fuel cells, MCFCs don't require an external reformer to convert more energy-dense fuels to hydrogen. Due to the high temperatures at which MCFCs operate, these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.

Molten carbonate fuel cells are not prone to carbon monoxide or carbon dioxide "poisoning"—they can even use carbon oxides as fuel—making them more attractive for fueling with gases made from coal. Because they are more resistant to impurities than other fuel cell types, scientists believe that they could even be capable of internal reforming of coal, assuming they can be made resistant to impurities such as sulfur and particulates that result from converting coal, a dirtier fossil fuel source than many others, into hydrogen.

The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life. Scientists are currently exploring corrosion-resistant materials for components as well as fuel cell designs that increase cell life without decreasing performance.

Solid Oxide Fuel Cells

Solid oxide fuel cells (SOFCs) use a hard, non-porous ceramic compound as the electrolyte. Since the electrolyte is a solid, the cells do not have to be constructed in the plate-like configuration typical of



other fuel cell types. SOFCs are expected to be around 50-60 percent efficient at converting fuel to electricity. In applications designed to capture and utilize the system's waste heat (co-generation), overall fuel use efficiencies could top 80-85 percent.

Solid oxide fuel cells operate at very high temperatures—around 1,000°C (1,830°F). High temperature operation removes the need for precious-metal catalyst, thereby reducing cost. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels and reduces the cost associated with adding a reformer to the system.

SOFCs are also the most sulfur-resistant fuel cell type; they can tolerate several orders of magnitude more sulfur than other cell types. In addition, they are not poisoned by carbon monoxide (CO), which can even be used as fuel. This allows SOFCs to use gases made from coal.

High-temperature operation has disadvantages. It results in a slow startup and requires significant thermal shielding to retain heat and protect personnel, which may be acceptable for utility applications but not for transportation and small portable applications. The high operating temperatures also place stringent durability requirements on materials. The development of low-cost materials with high durability at cell operating temperatures is the key technical challenge facing this technology.

Scientists are currently exploring the potential for developing lower-temperature SOFCs operating at or below 800°C that have fewer durability problems and cost less. Lower-temperature SOFCs produce less electrical power, however, and stack materials that will function in this lower temperature range have not been identified.

Regenerative Fuel Cells


Regenerative fuel cells produce electricity from hydrogen and oxygen and generate heat and water as byproducts, just like other fuel cells. However, regenerative fuel cell systems can also use electricity from solar power or some other source to divide the excess water into oxygen and hydrogen fuel—this process is called "electrolysis." This is a comparatively young fuel cell technology being developed by NASA and others.

Comparison of Fuel Cell

Technologies

Each fuel cell technology has advantages and disadvantages. See how fuel cell technologies compare with each other.

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